Prentice Hall

EARTH SCIENCE

Tarbuck ◆ Lutgens

Chapter 8

Earthquakes and Earth's Interior

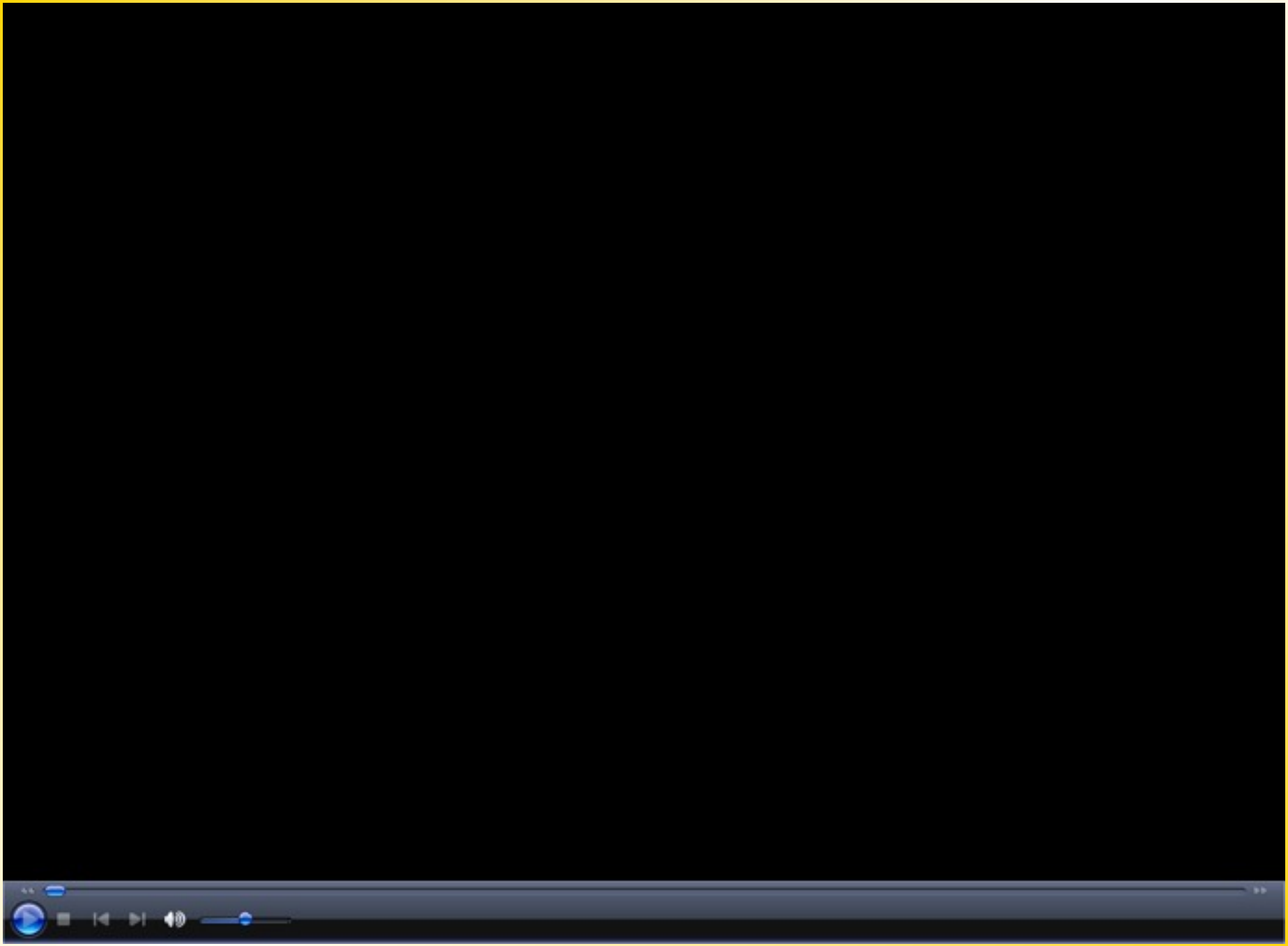
8 Earthquakes and Earth's Interior

Chapter 8

- State Standards - **Dynamic Earth Processes**

3 – Plate tectonics operating over geologic time has changed the patterns of land, sea, and mountains on Earth's surface. As the basis for understanding this concept:

- 3d – *Students know* why and how earthquakes occur and the scales used to measure their intensity and magnitude.



Objective

Chapter 8.1

- Objective:
  - Students will learn what causes an earthquake.

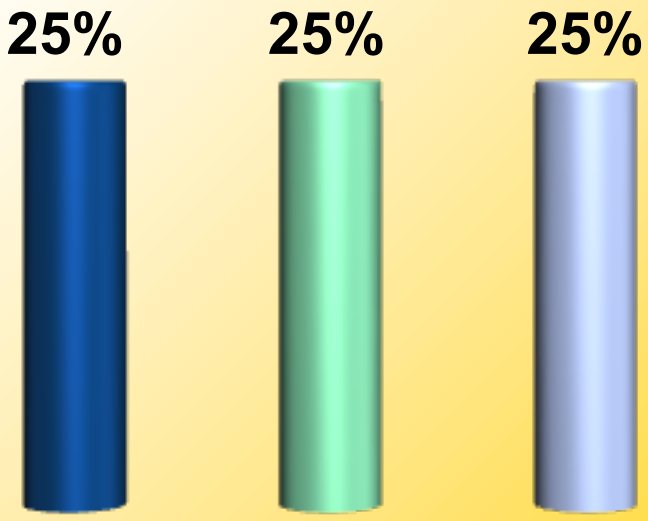
8.1 What Is an Earthquake?

Earthquakes

- An **earthquake** is the vibration of Earth produced by the rapid release of energy
- Focus and Epicenter
  - **Focus** is the point within Earth where the earthquake starts.
  - **Epicenter** is the location on the surface directly above the focus.
- Faults
  - **Faults** are fractures in Earth where movement has occurred.

An earthquake's epicenter is ____.

1. the place on the surface directly above the focus
2. a spot halfway between the focus and the surface
3. the spot below the focus
4. any spot along the nearest fault



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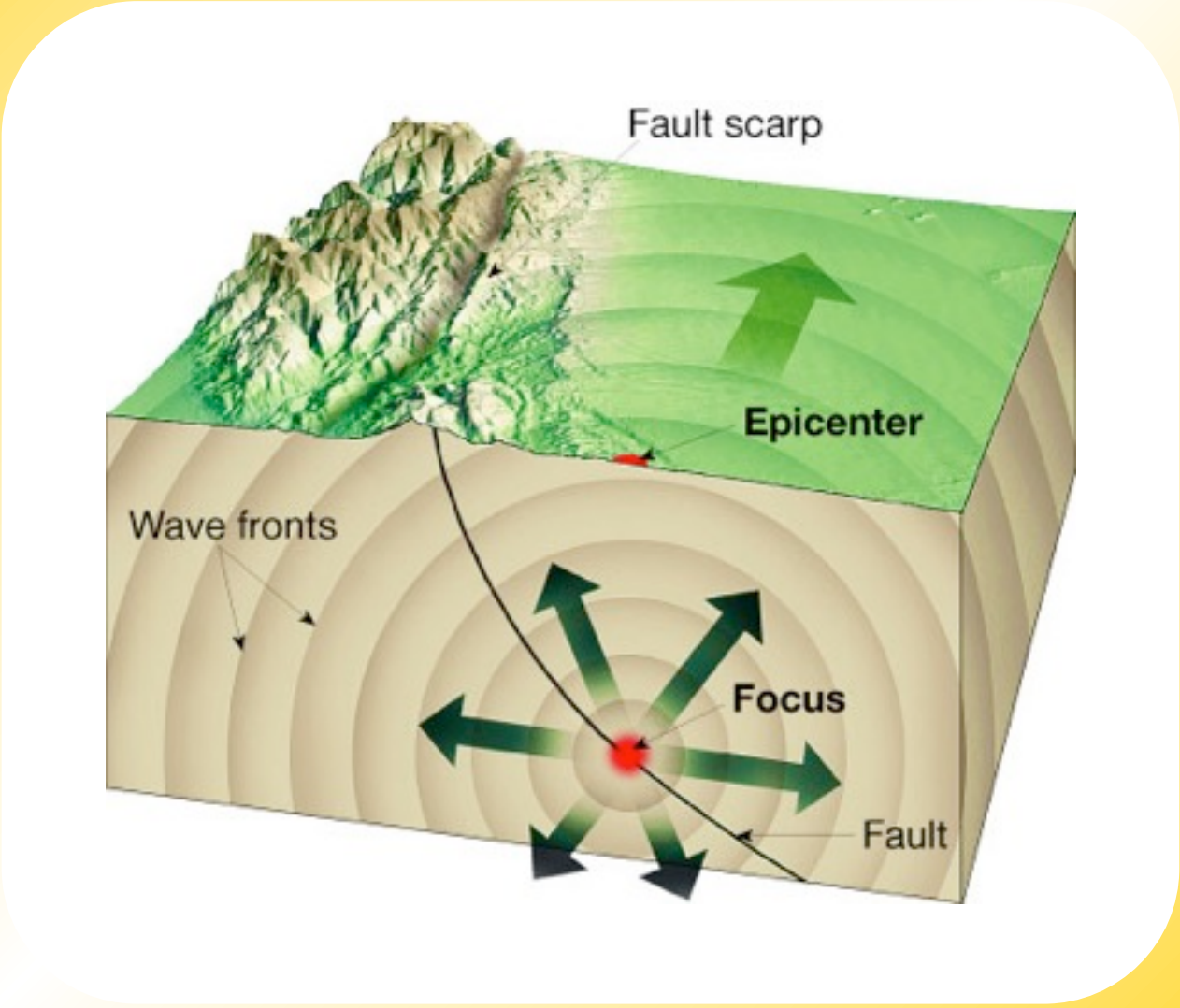
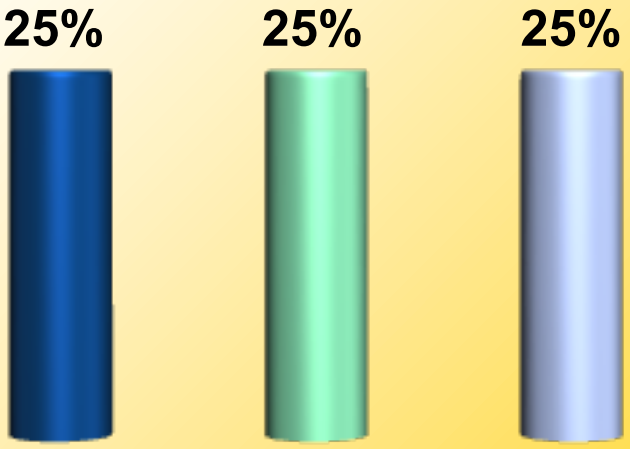
Focus, Epicenter, and Fault



When an earthquake occurs, energy radiates in all directions from its source, which is called the _____.

1. epicenter
2. focus
3. fault
4. seismic center



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Slippage Along a Fault

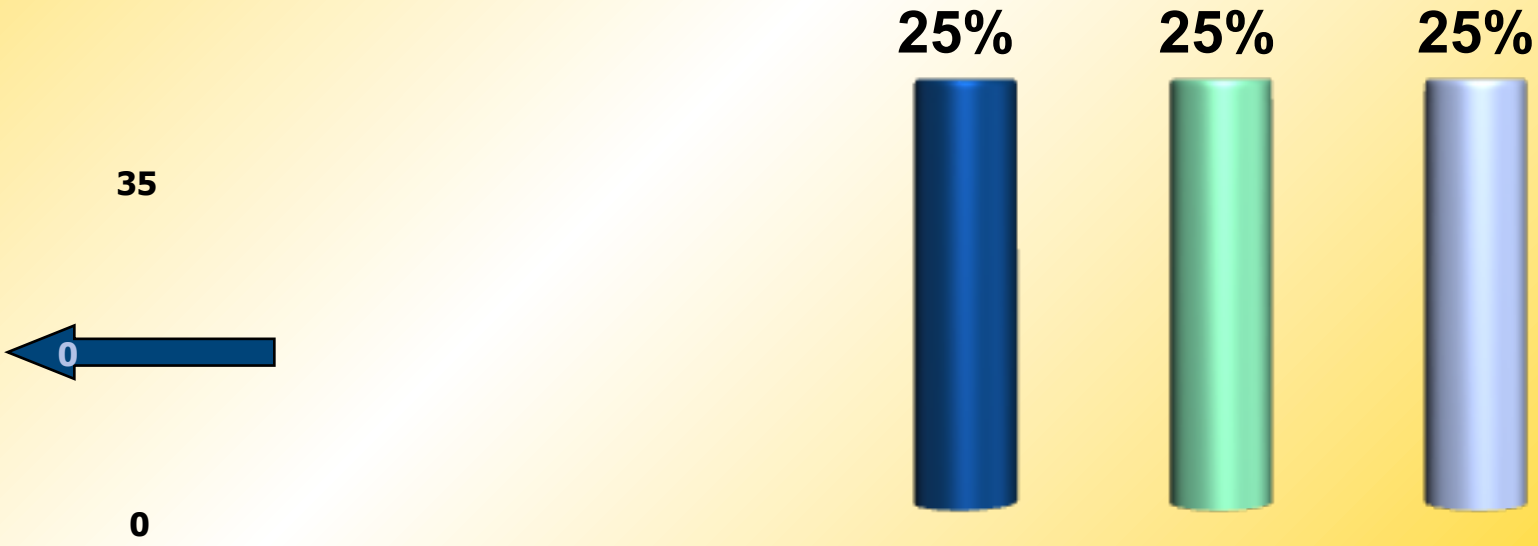
8.1 What Is an Earthquake?

Cause of Earthquakes

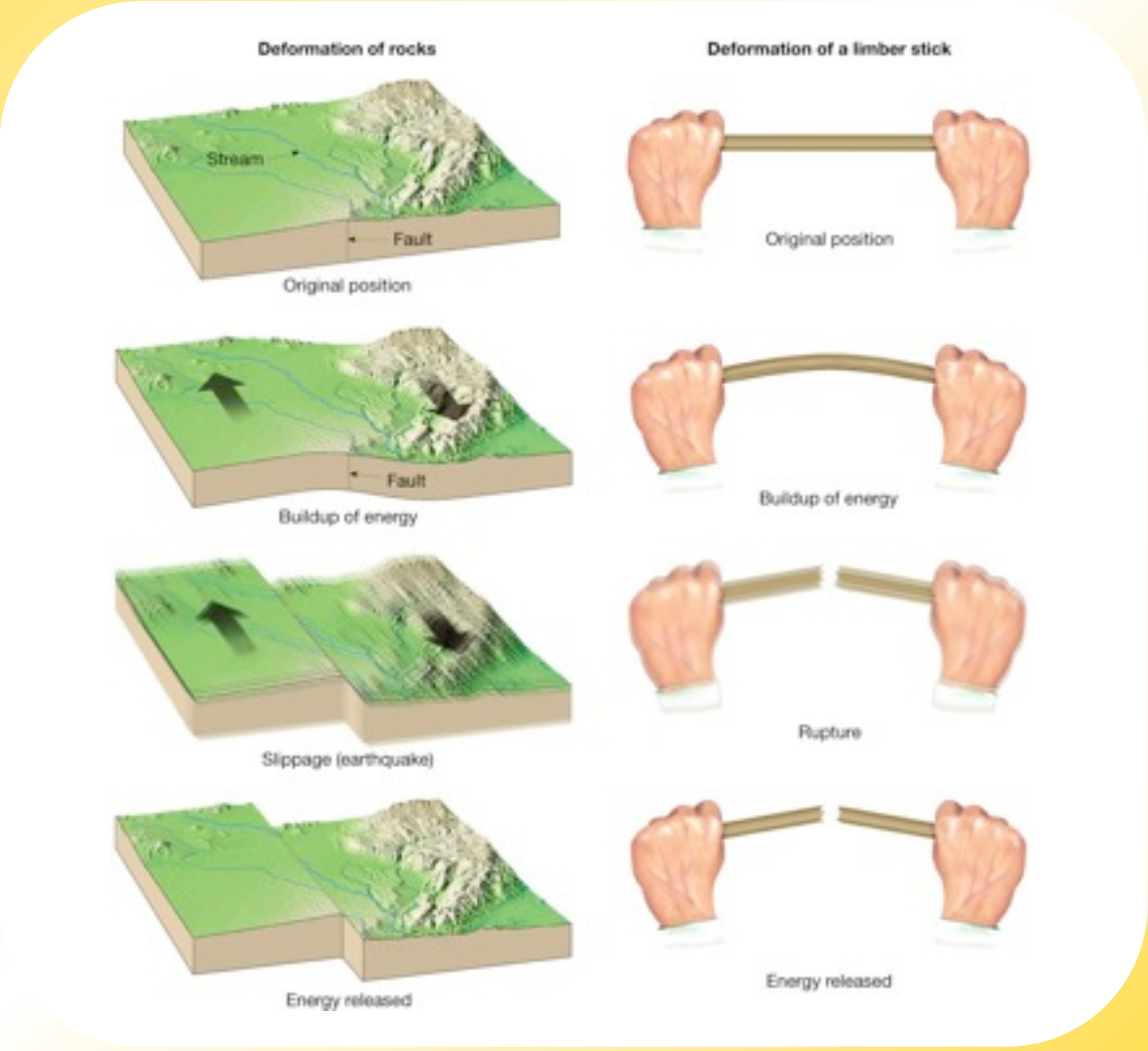
- **Elastic Rebound Hypothesis**
  - Most earthquakes are produced by the rapid release of elastic energy stored in rock that has been subjected to great forces.
  - When the strength of the rock is exceeded, it suddenly breaks, causing the vibrations of an earthquake.

Which of the following causes earthquakes?

1. elastic rebound
2. Richter scale
3. release of heat
4. frictional heating



Elastic Rebound Hypothesis



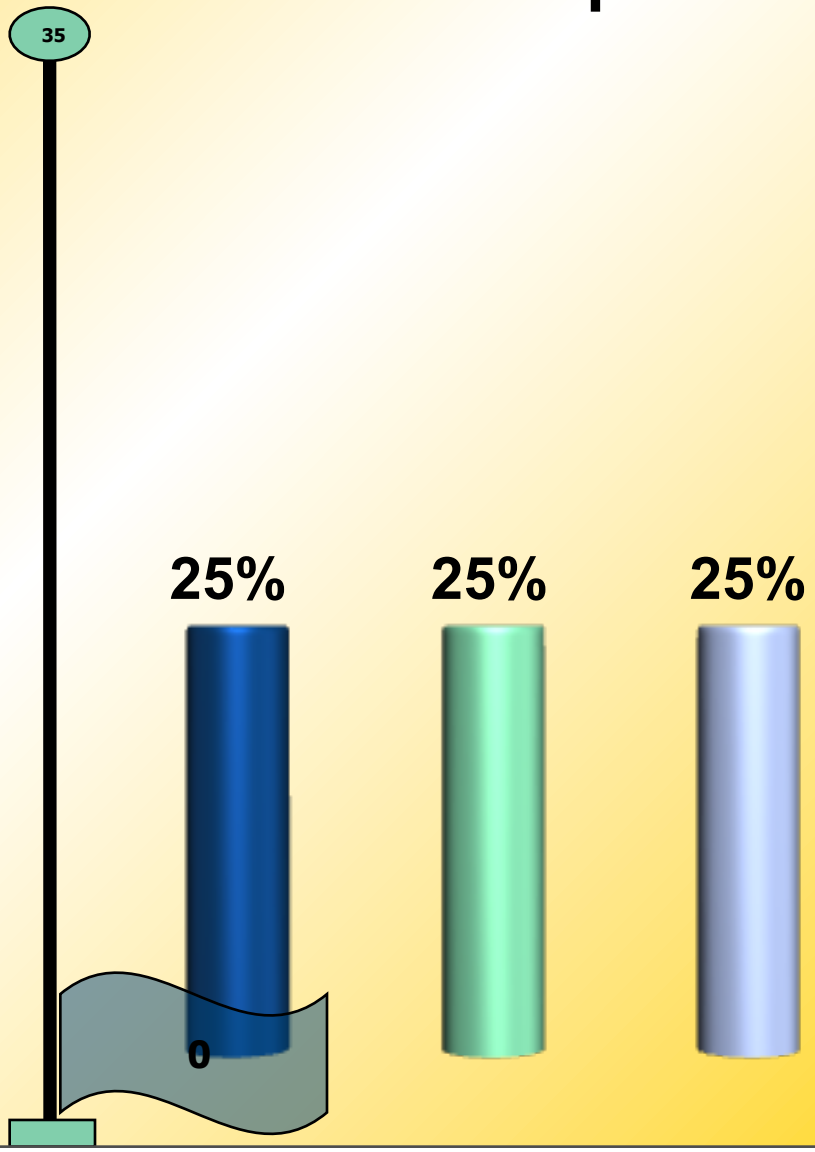
8.1 What Is an Earthquake?

Cause of Earthquakes

- Aftershocks and Foreshocks
  - An **aftershock** is a small earthquake that follows the main earthquake.
  - A **foreshock** is a small earthquake that often precedes a major earthquake.

Major earthquakes are sometimes preceded by smaller earthquakes called _____.

1. aftershocks
2. focus shocks
3. surface waves
4. foreshocks



Objective

Chapter 8.2

- Objective:
  - Students will learn about earthquake waves,

8.2 Measuring Earthquakes

Earthquake Waves

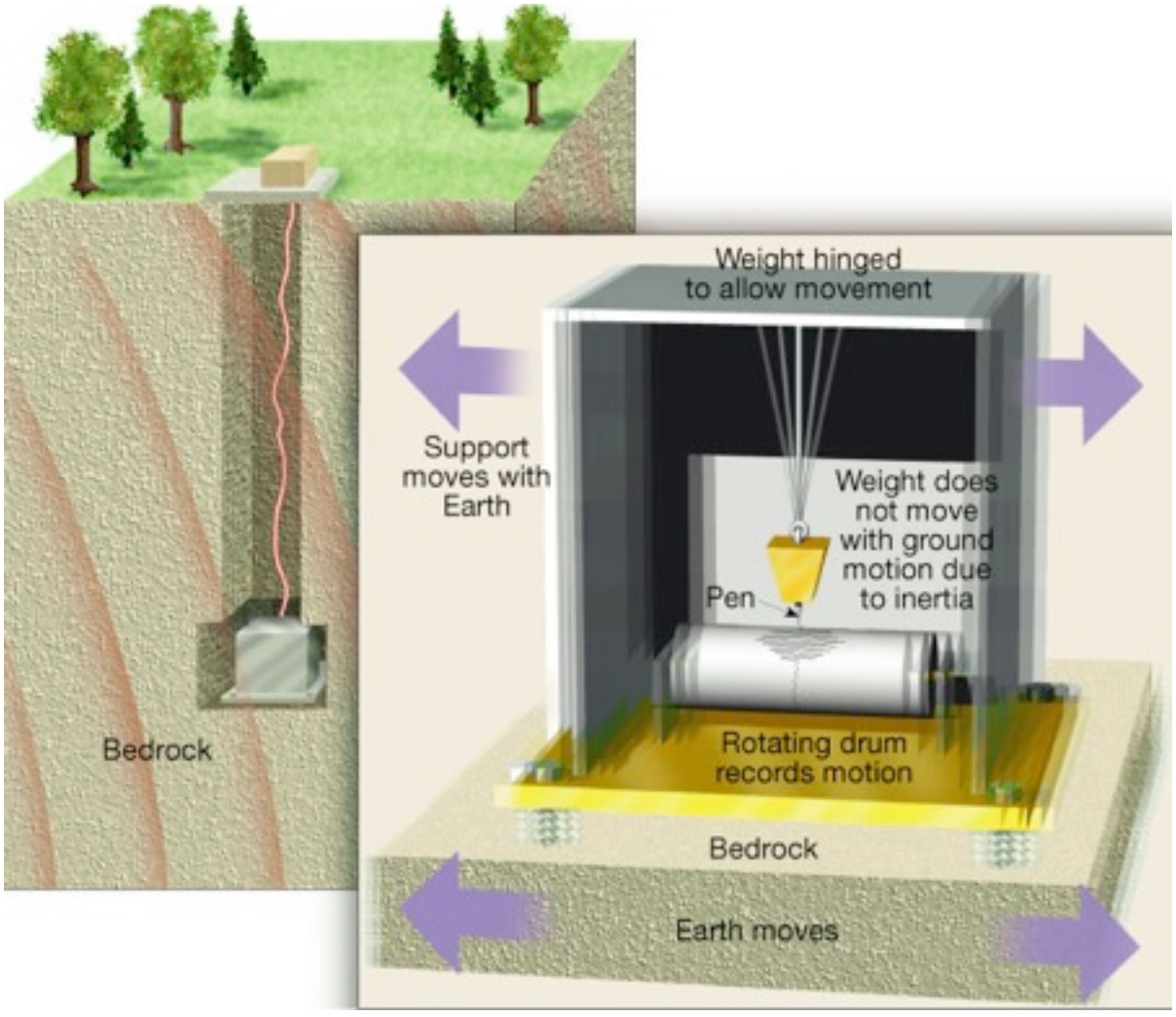
- **Seismographs** are instruments that record earthquake waves.
- **Seismograms** are traces of amplified, electronically recorded ground motion made by seismographs.
- **Surface waves** are seismic waves that travel along Earth's outer layer. These are the most destructive waves

8.2 Measuring Earthquakes

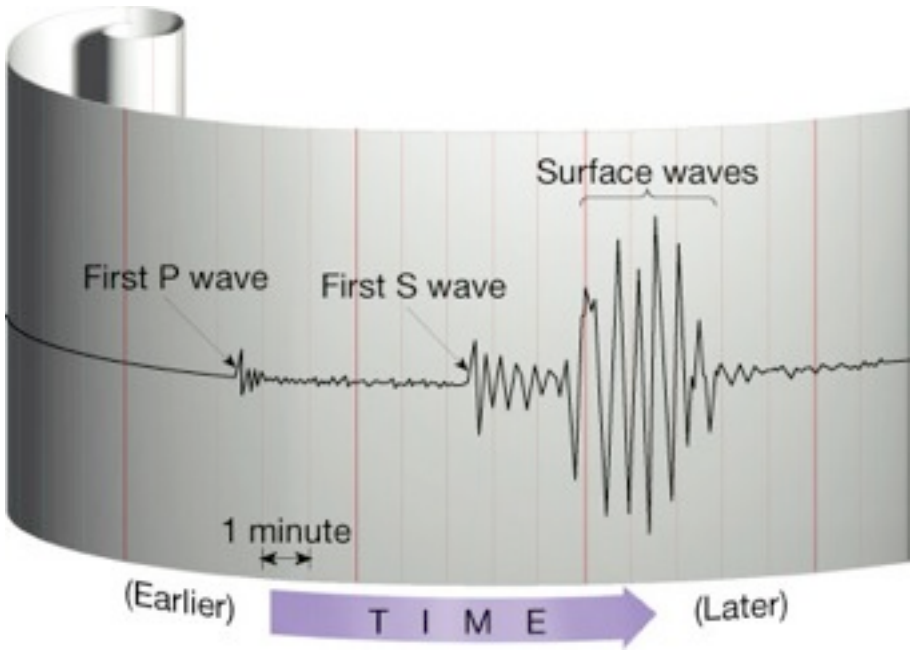
Overall, which seismic waves are the most destructive?

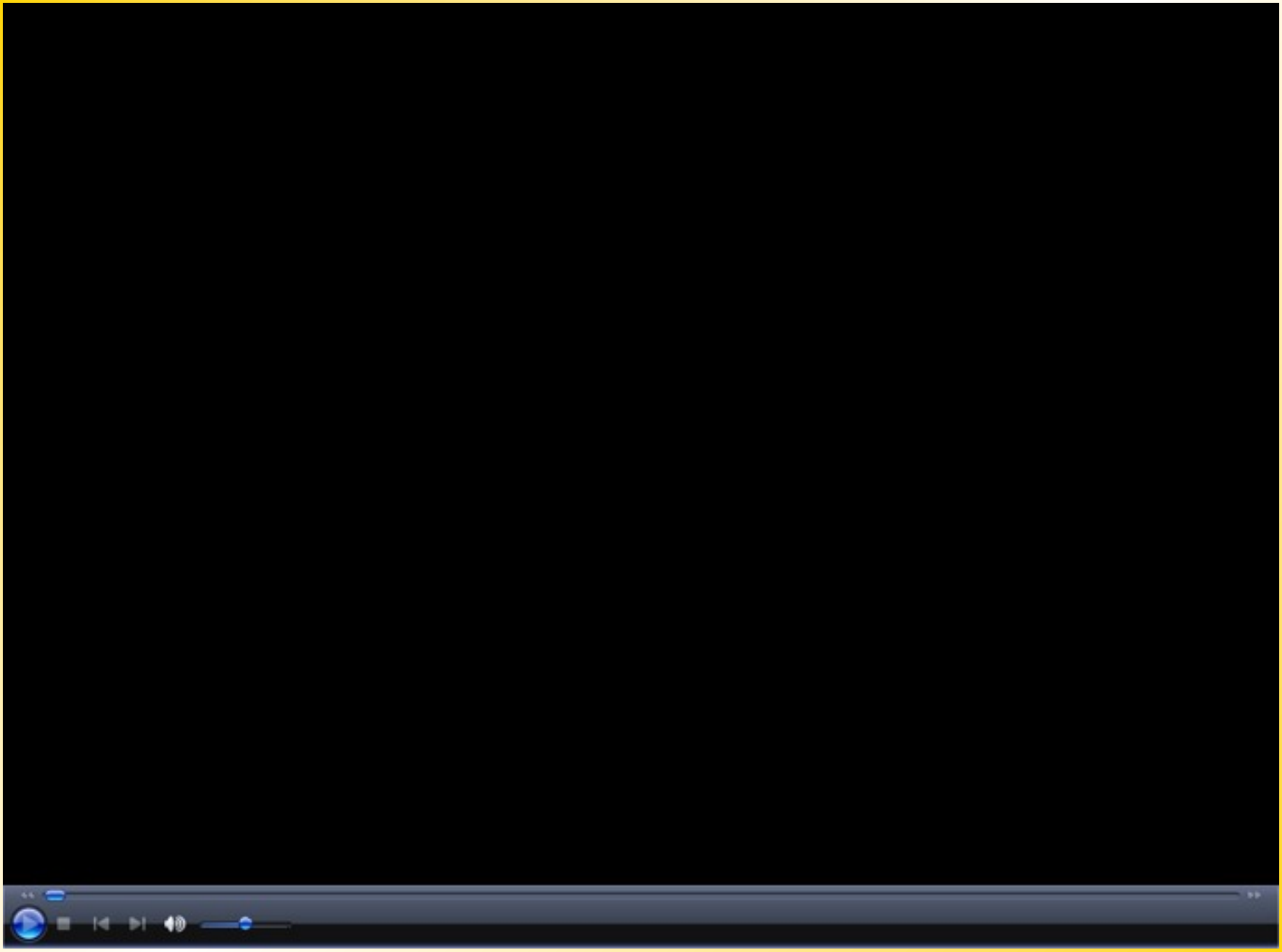
1. P waves
2. S waves
3. compression waves
4. surface waves

Seismograph



Seismogram


Surface waves
First P wave
First S wave
1 minute
(Earlier)
T I M E
(Later)



8.2 Measuring Earthquakes

Earthquake Waves

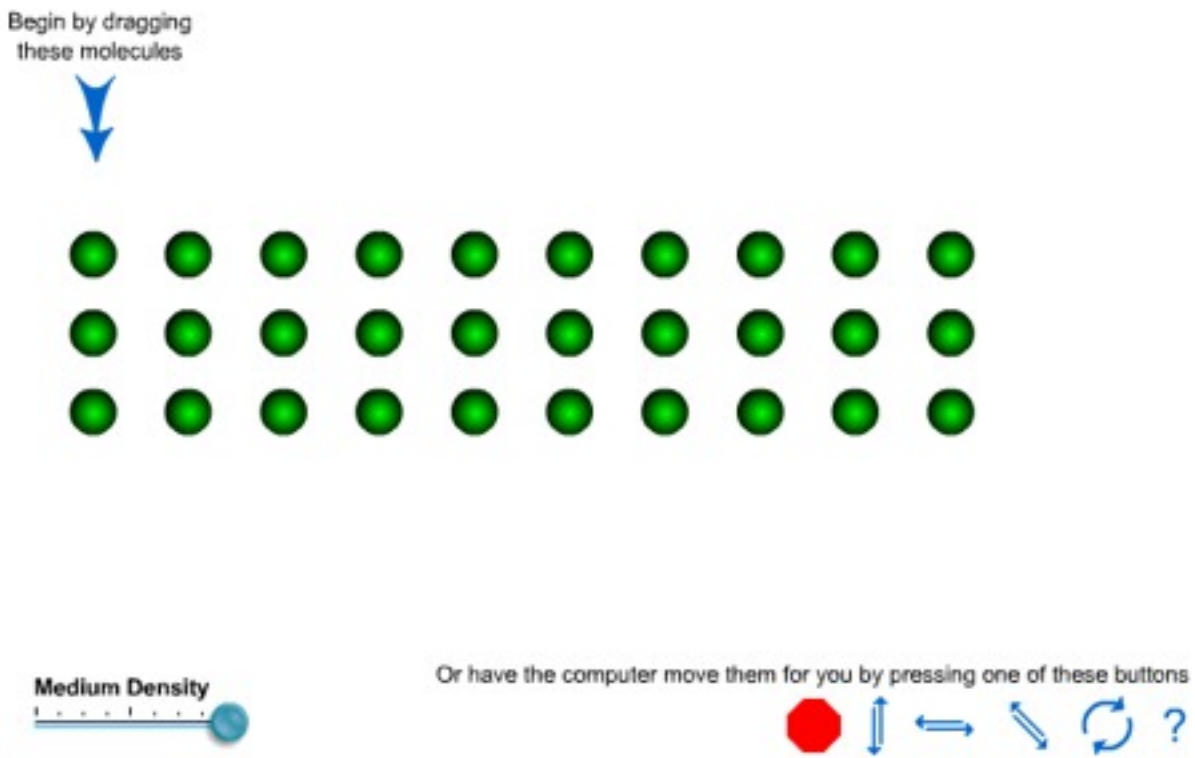
- Body Waves
  - Identified as P waves or S waves
  - **P waves**
    - Are push-pull waves that push (compress) and pull (expand) in the direction that the waves travel
    - Travel through solids, liquids, and gases
    - Have the greatest velocity of all earthquake waves

8.2 Measuring Earthquakes

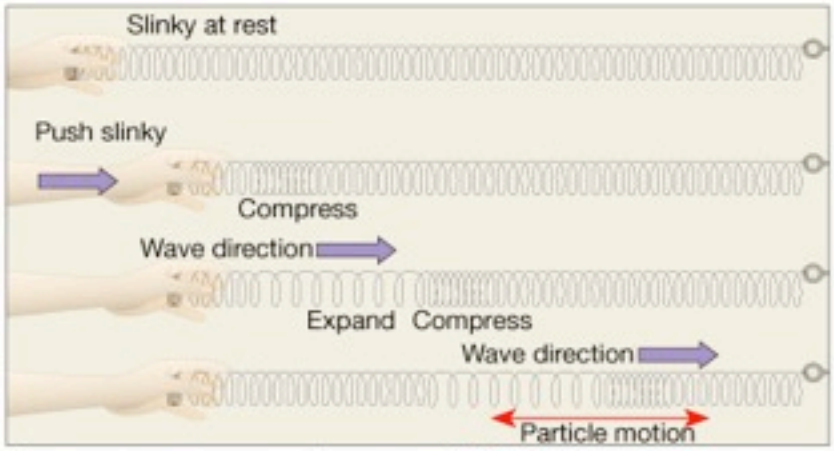
Earthquake Waves

- Body Waves
  - **S waves**
  - – Seismic waves that travel along Earth's outer layer
  - – Shake particles at right angles to the direction that they travel
  - – Travel only through solids
  - – Slower velocity than P waves
- A seismogram shows all three types of seismic waves—surface waves, P waves, and S waves.

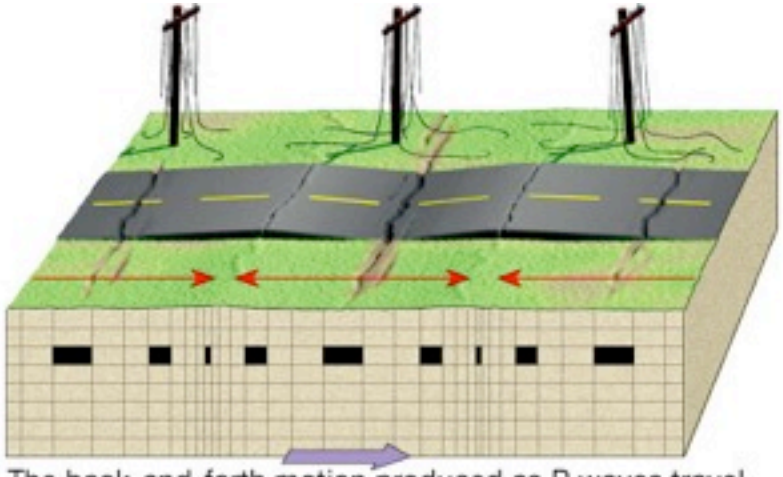
Seismic Waves



Seismic Waves

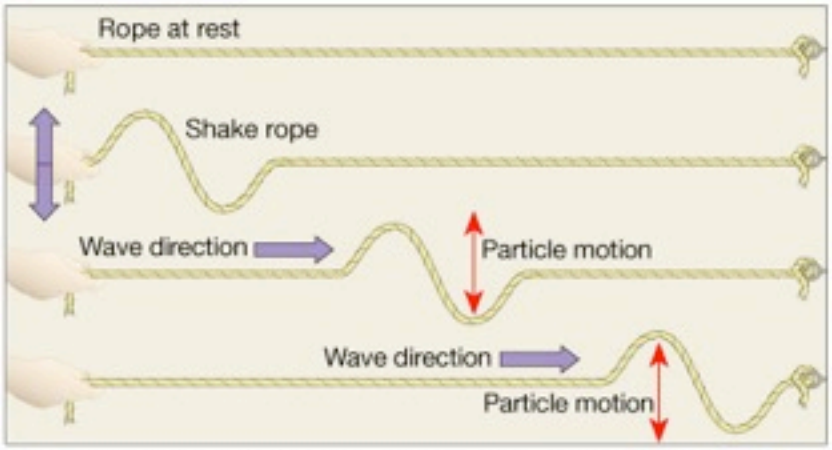


P waves are compression waves that alternately compress and expand the material through which they pass.

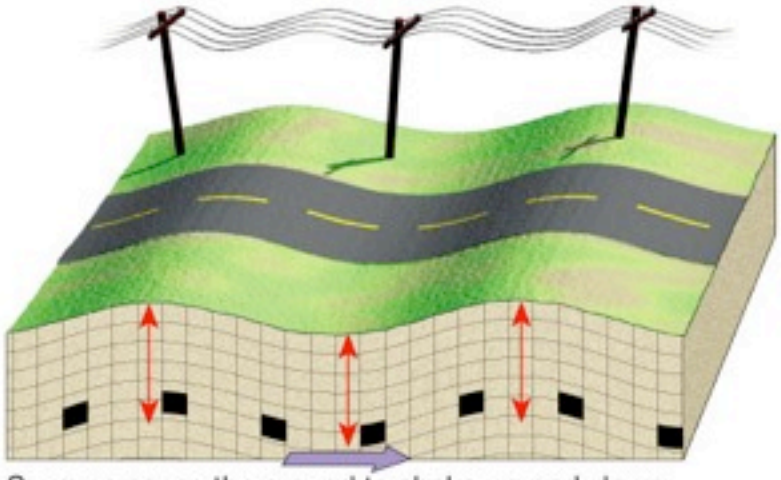


The back-and-forth motion produced as P waves travel along the surface can cause the ground to buckle and fracture.

Seismic Waves

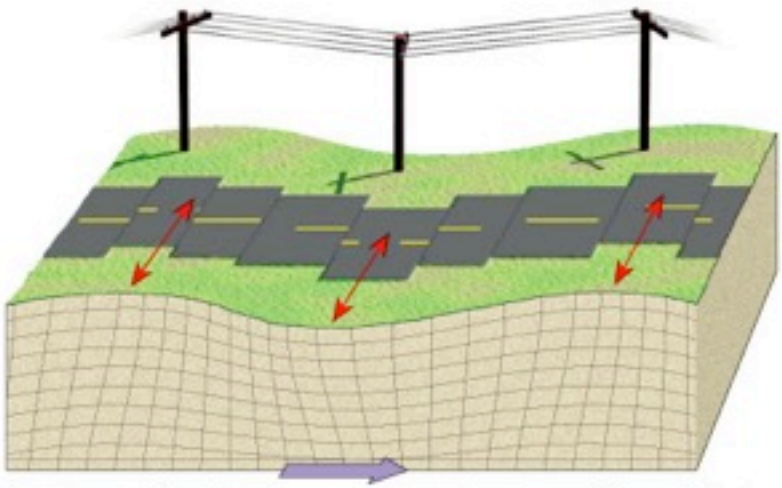


S waves are transverse waves which cause material to shake at right angles to the direction of wave motion. The length of the red arrow is the displacement, or amplitude, of the S wave.

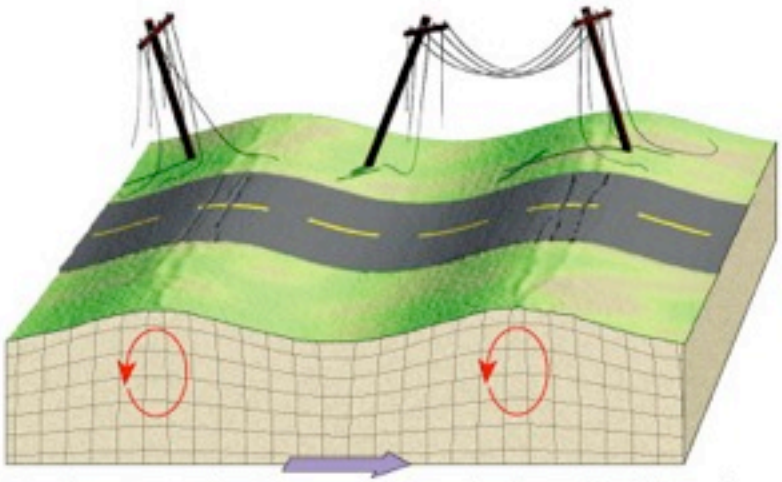


S waves cause the ground to shake up-and-down and sideways.

Seismic Waves



One type of surface wave moves the ground from side to side and can damage the foundations of buildings.



Another type of surface wave travels along Earth's surface much like rolling ocean waves. The arrows show the movement of rock as the wave passes. The motion follows the shape of an ellipse.

Objective

Chapter 8.2

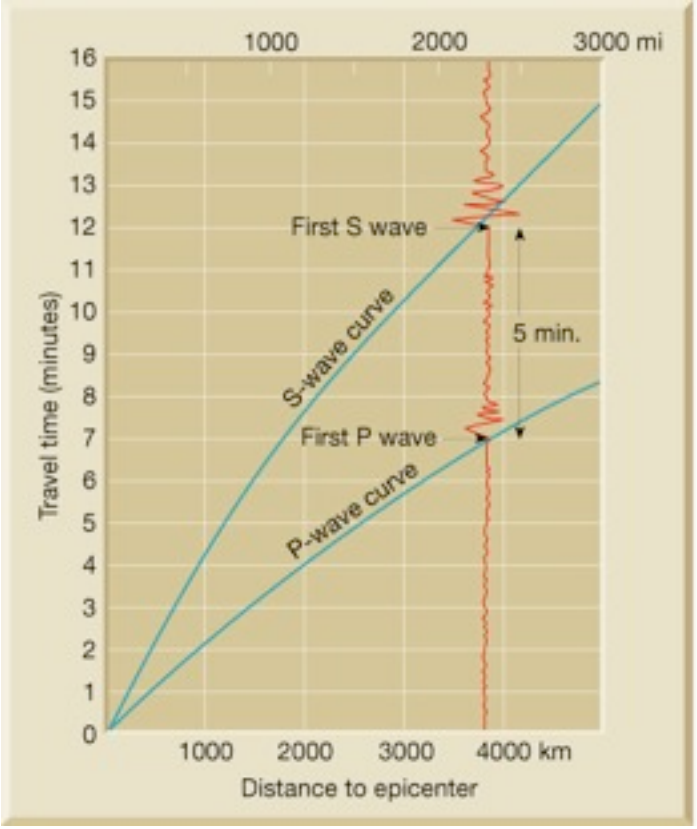
- Objective:
  - Students will learn how to measure and locate an earthquake

8.2 Measuring Earthquakes

Locating an Earthquake

- Earthquake Distance
  - The epicenter is located using the difference in the arrival times between P and S wave recordings, which are related to distance.
- Earthquake Direction
  - Travel-time graphs from three or more seismographs can be used to find the exact location of an earthquake epicenter.
- Earthquake Zones
  - About 95 percent of the major earthquakes occur in a few narrow zones.

Locating an Earthquake



8.2 Measuring Earthquakes

Measuring Earthquakes

- Historically, scientists have used two different types of measurements to describe the size of an earthquake —intensity and magnitude.
- Intensity is the measure of the amount of shaking produced by an earthquake
- Magnitude is the measure of the seismic wave

8.2 Measuring Earthquakes

Measuring Earthquakes

- Richter Scale
  - Based on the amplitude of the largest seismic wave
  - Each unit of Richter magnitude equates to roughly a 32-fold energy increase
  - Does not estimate adequately the size of very large earthquakes

8.2 Measuring Earthquakes

Measuring Earthquakes

- **Momentum Magnitude**
  - Derived from the amount of displacement that occurs along the fault zone
  - Moment magnitude is the most widely used measurement for earthquakes because it is the only magnitude scale that estimates the energy released by earthquakes.
  - Measures very large earthquakes

Earthquake Magnitudes

Table 1 Earthquake Magnitudes and Expected World Incidence

Moment Magnitudes	Effects Near Epicenter	Estimated Number per Year
< 2.0	Generally not felt, but can be recorded	> 600,000
2.0–2.9	Potentially perceptible	> 300,000
3.0–3.9	Rarely felt	> 100,000
4.0–4.9	Can be strongly felt	13,500
5.0–5.9	Can be damaging shocks	1,400
6.0–6.9	Destructive in populous regions	110
7.0–7.9	Major earthquakes; inflict serious damage	12
8.0 and above	Great earthquakes; destroy communities near epicenter	0–1

Some Notable Earthquakes

Table 2 Some Notable Earthquakes

Year	Location	Deaths (est.)	Magnitude†	Comments
*1886	Charleston, South Carolina	60		Greatest historical earthquake in the eastern United States
*1906	San Francisco, California	1500	7.8	Fires caused extensive damage.
1923	Tokyo, Japan	143,000	7.9	Fire caused extensive destruction.
1960	Southern Chile	5700	9.6	Possibly the largest-magnitude earthquake ever recorded
*1964	Alaska	131	9.2	Greatest North American earthquake
1970	Peru	66,000	7.8	Large rockslide
*1971	San Fernando, California	65	6.5	Damages exceeded $1 billion.
1985	Mexico City	9500	8.1	Major damage occurred 400 km from epicenter.
1988	Armenia	25,000	6.9	Poor construction practices caused great damage.
*1989	Loma Prieta, California	62	6.9	Damages exceeded $6 billion.
1990	Iran	50,000	7.3	Landslides and poor construction practices caused great damage.
1993	Latur, India	10,000	6.4	Located in stable continental interior
*1994	Northridge, California	57	6.7	Damages exceeded $40 billion.
1995	Kobe, Japan	5472	6.9	Damages estimated to exceed $100 billion.
1999	Izmit, Turkey	17,127	7.4	Nearly 44,000 injured and more than 250,000 displaced.
1999	Chi Chi, Taiwan	2300	7.6	Severe destruction; 8700 injuries
2001	El Salvador	1000	7.6	Triggered many landslides
2001	Bhuj, India	20,000†	7.9	1 million or more homeless

*U.S. earthquakes
†Widely differing magnitudes have been estimated for some earthquakes. When available, moment magnitudes are used.
SOURCE: U.S. Geological Survey

Objective

Chapter 8.3

- Objective:
  - Students will learn about seismic vibrations.

8.3 Destruction from Earthquakes

Seismic Vibrations

- The damage to buildings and other structures from earthquake waves depends on several factors. These factors include the intensity and duration of the vibrations, the nature of the material on which the structure is built, and the design of the structure.

Earthquake Damage

8.3 Destruction from Earthquakes

Seismic Vibrations

- Building Design
  - Factors that determine structural damage
  - – Intensity of the earthquake
  - – Unreinforced stone or brick buildings are the most serious safety threats
  - – Nature of the material upon which the structure rests
  - – The design of the structure

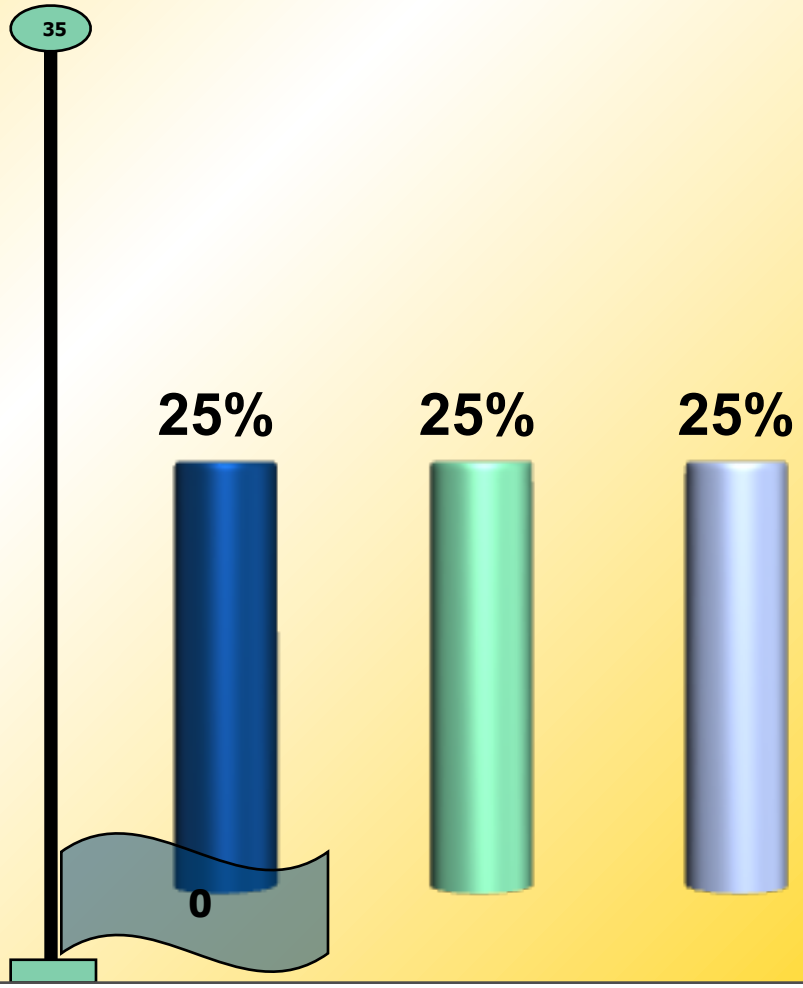
8.3 Destruction from Earthquakes

Seismic Vibrations

- **Liquefaction**
  - Saturated material turns fluid
  - Underground objects may float to surface

In areas where unconsolidated sediments are saturated with water, earthquakes can turn stable soil into a fluid through a process called ____.

1. tidal effect
2. fault creep
3. liquefaction
4. underwater landslide

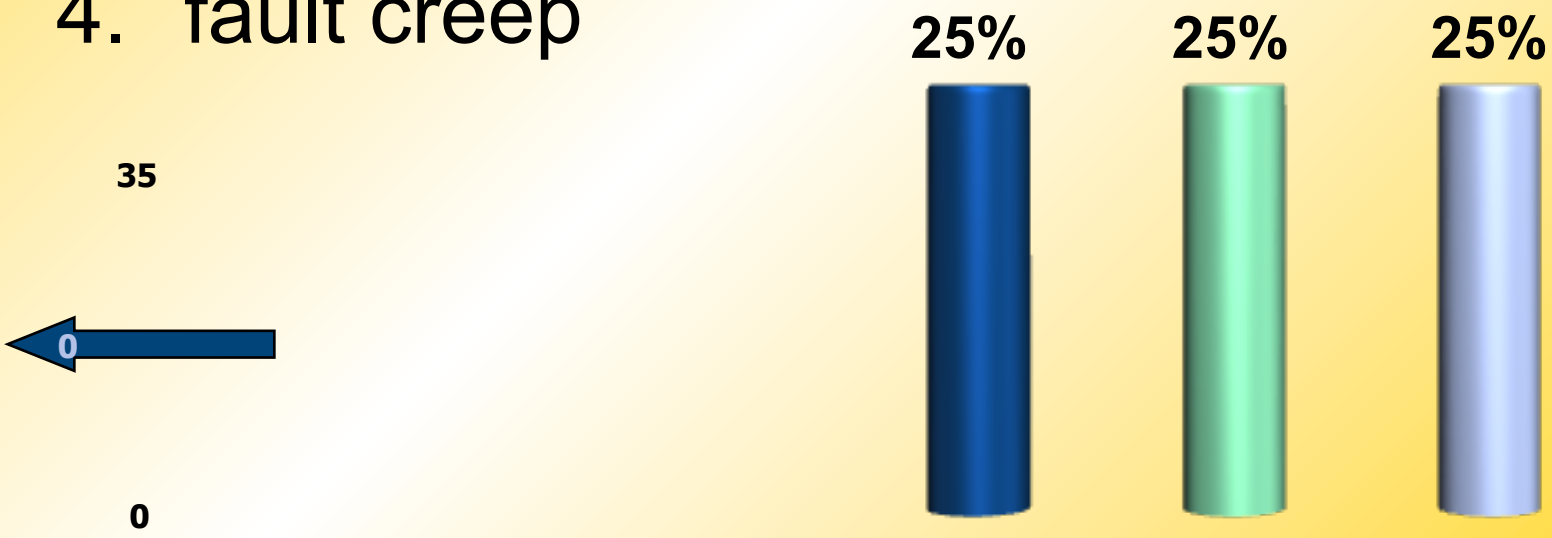


Effects of Subsidence Due to Liquefaction

Effects of Subsidence Due to Liquefaction

A building that settles unevenly after an earthquake is evidence of ____.

1. a tsunami
2. liquefaction
3. an underwater landslide
4. fault creep



Objective

Chapter 8.3

- Objective:
  - Students will learn about tsunamis.

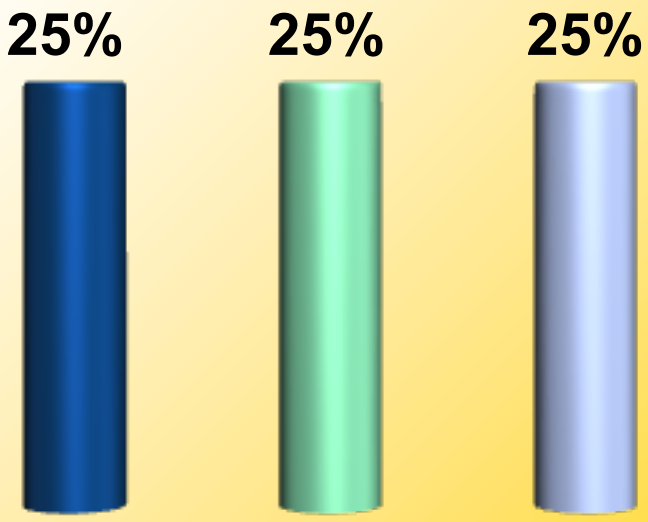
8.3 Destruction from Earthquakes

Tsunamis

- Cause of Tsunamis
  - A **tsunami** triggered by an earthquake occurs where a slab of the ocean floor is displaced vertically along a fault.
  - A tsunami also can occur when the vibration of a quake sets an underwater landslide into motion.
  - *Tsunami* is the Japanese word for "seismic sea wave."

Tsunamis are ____.

1. often generated by movements of the ocean floor
2. waves that are produced by tidal forces
3. waves that cannot cause damage on land
4. also known as tidal waves



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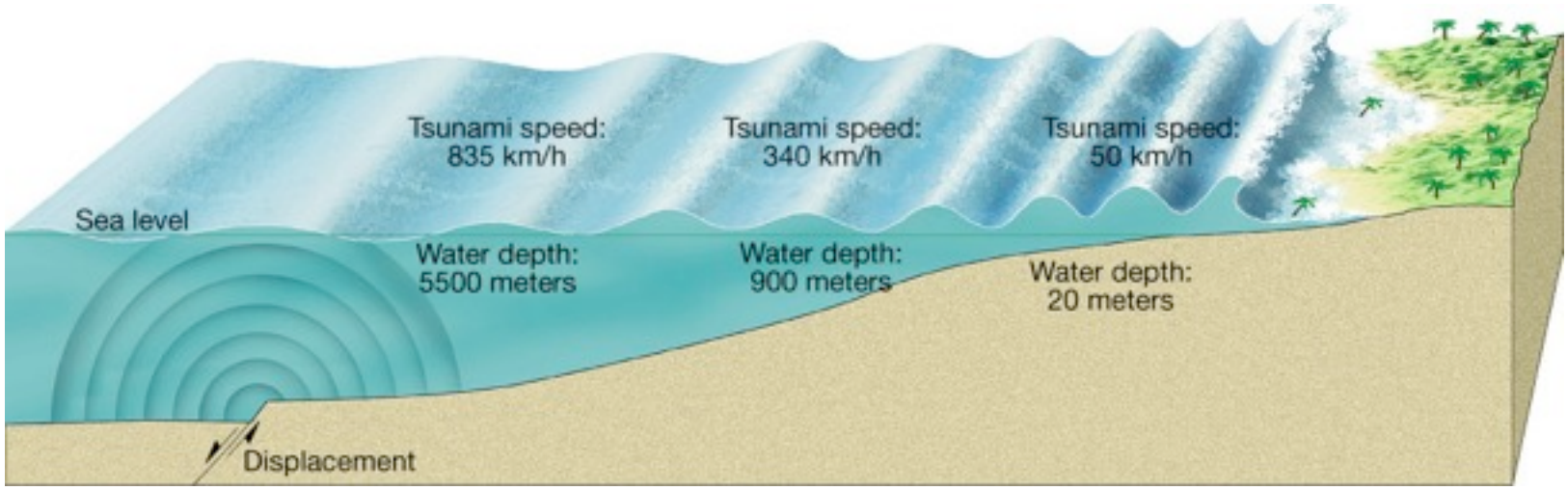
Movement of a Tsunami



8.3 Destruction from Earthquakes

Tsunamis

- Tsunami Warning System
  - Large earthquakes are reported to Hawaii from Pacific seismic stations.
  - Although tsunamis travel quickly, there is sufficient time to evacuate all but the area closest to the epicenter.

8.3 Destruction from Earthquakes

Other Dangers

- Landslides
  - With many earthquakes, the greatest damage to structures is from landslides and ground subsidence, or the sinking of the ground triggered by vibrations.
- Fire
  - In the San Francisco earthquake of 1906, most of the destruction was caused by fires that started when gas and electrical lines were cut.

Landslide Damage

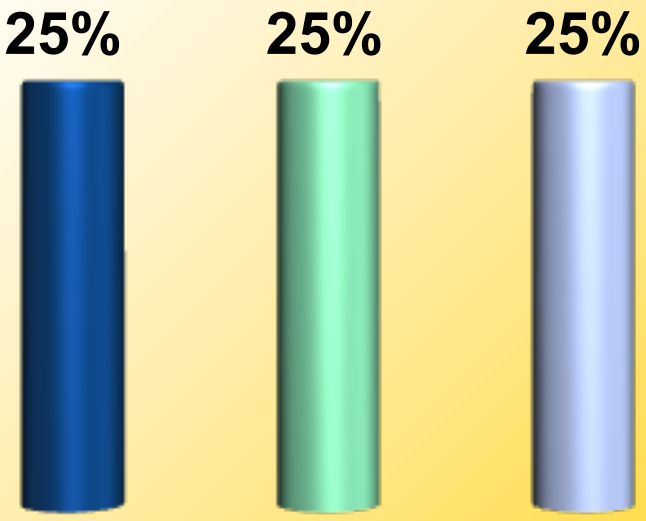
8.3 Destruction from Earthquakes

Predicting Earthquakes

- Short-Range Predictions
  - So far, methods for short-range predictions of earthquakes have not been successful.
- Long-Range Forecasts
  - Scientists don't yet understand enough about how and where earthquakes will occur to make accurate long-term predictions.
  - A **seismic gap** is an area along a fault where there has not been any earthquake activity for a long period of time.

Which of the following is used in an attempt to make long-range predictions of when earthquakes will occur?

1. strain in rocks near faults
2. height of ocean waves after earthquakes
3. changes in the color of rocks near faults
4. study of historical records



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Objective

Chapter 8.4

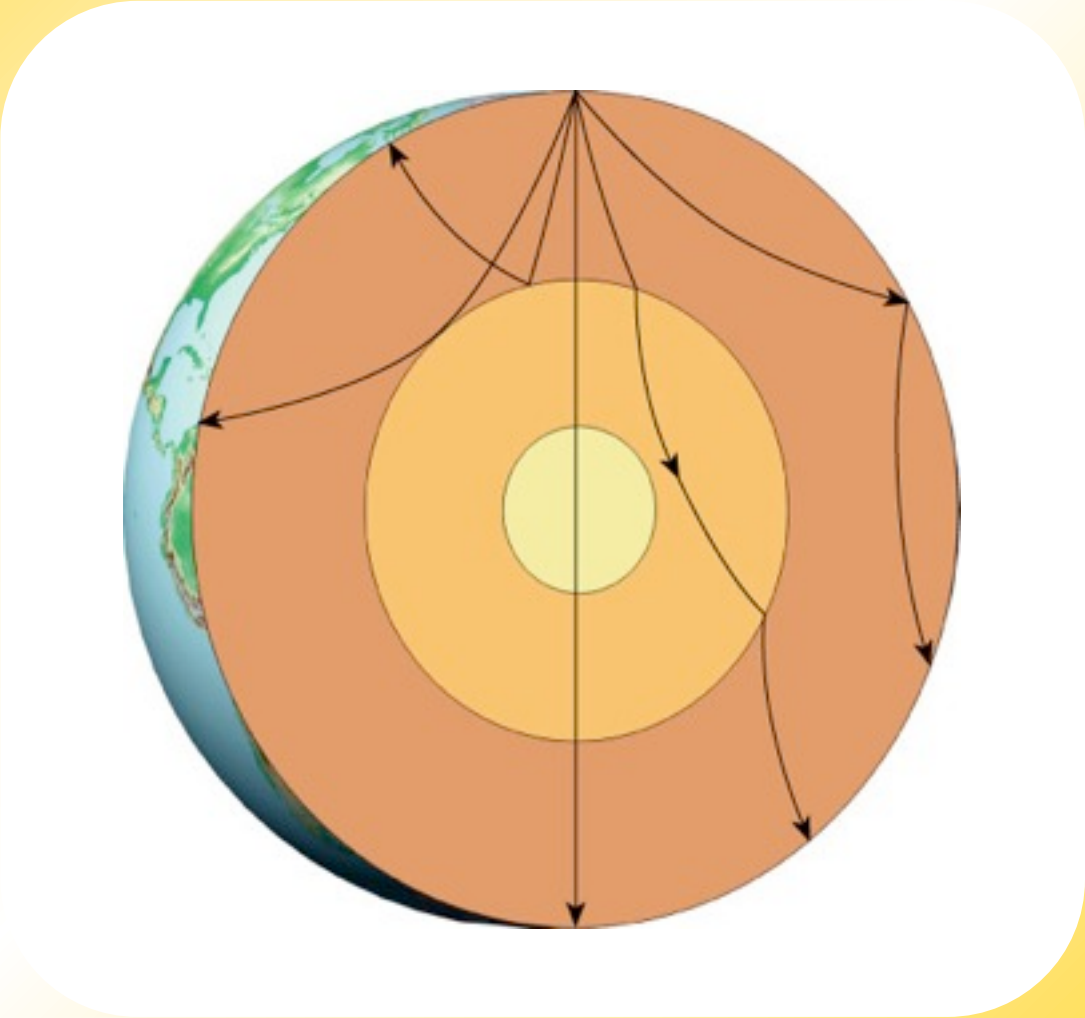
- Objective:
  - Students will learn Earth's layered structure by composition.

8.4 Earth's Layered Structure

Layers Defined by Composition

- Earth's interior consists of three major zones defined by their chemical composition—the **crust, mantle,** and **core.**
- Crust
  - Thin, rocky outer layer
  - Varies in thickness
  - – Roughly 7 km in oceanic regions
  - – Continental crust averages 8–40 km
  - – Exceeds 70 km in mountainous regions

Seismic Waves Paths Through the Earth



8.4 Earth's Layered Structure

Layers Defined by Composition

- Crust
  - Continental crust
  - Upper crust composed of granitic rocks
  - Lower crust is more akin to basalt
  - Average density is about 2.7 g/cm3
  - Up to 4 billion years old

8.4 Earth's Layered Structure

Layers Defined by Composition

- Crust
  - Oceanic crust
  - Basaltic composition
  - Density about 3.0 g/cm3
  - Younger (180 million years or less) than the continental crust

8.4 Earth's Layered Structure

Layers Defined by Composition

- Mantle
  - Below crust to a depth of 2900 kilometers
  - Composition of the uppermost mantle is the igneous rock peridotite (changes at greater depths).

8.4 Earth's Layered Structure

Layers Defined by Composition

- Core
  - Below mantle
  - Sphere with a radius of 3486 kilometers
  - Composed of an iron-nickel alloy
  - Average density of nearly 11 g/cm3

Objective

Chapter 8.4

- Objective:
  - Students will learn Earth's layered structure by physical properties.

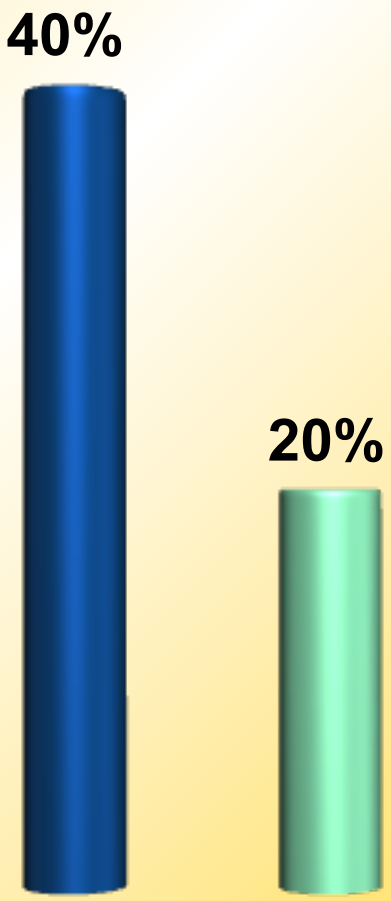
8.4 Earth's Layered Structure

Layers Defined by Physical Properties

- **Lithosphere**
  - Crust and uppermost mantle (about 100 km thick)
  - Cool, rigid, solid
- **Asthenosphere**
  - Beneath the lithosphere
  - Upper mantle
  - To a depth of about 660 kilometers
  - Soft, weak layer that is easily deformed

What layers of Earth make up the lithosphere?

1. the crust and lower mantle
2. the crust and upper mantle
3. the continental crust and oceanic crust
4. the upper and lower mantle



8.4 Earth's Layered Structure

Layers Defined by Physical Properties

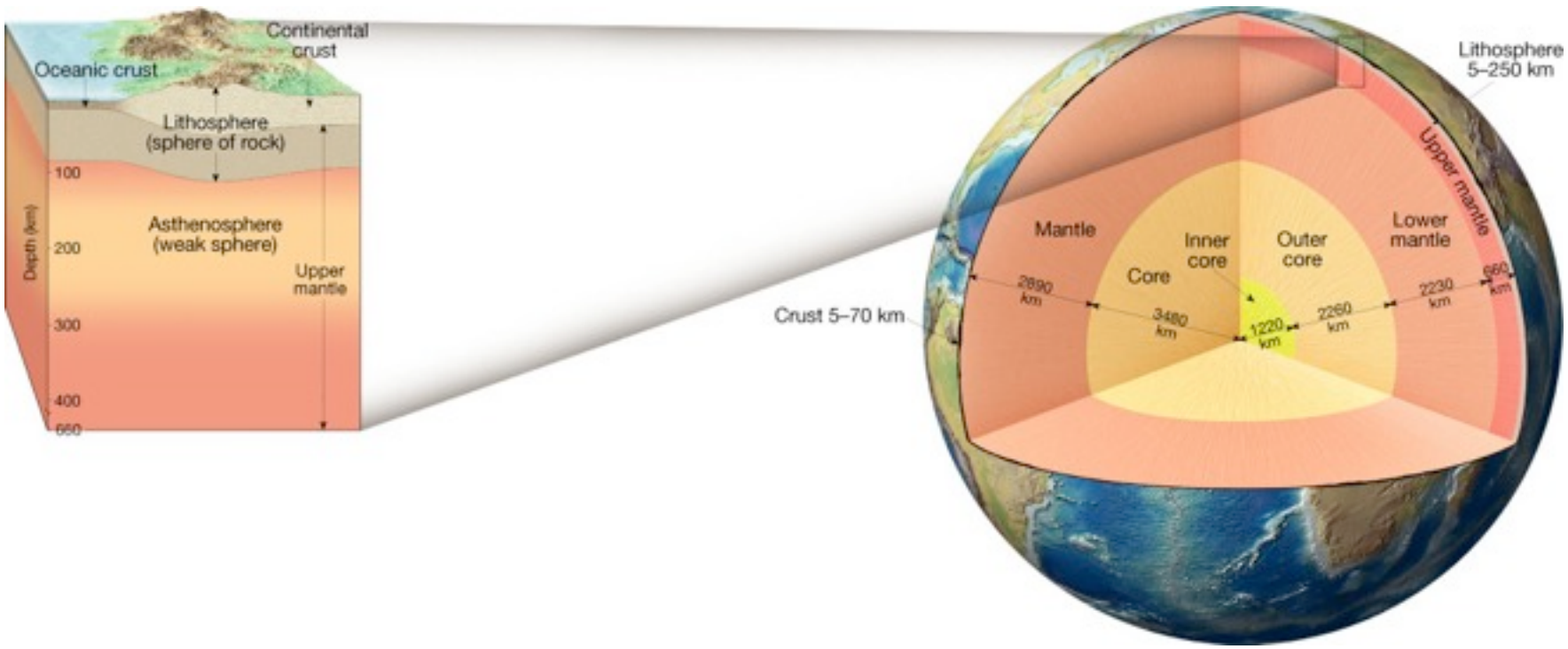
- Lower Mantle
  - 660–2900 km
  - More rigid layer
  - Rocks are very hot and capable of gradual flow.

8.4 Earth's Layered Structure

Layers Defined by Physical Properties

- **Inner Core**
  - Sphere with a radius of 1216 km
  - Behaves like a solid
- **Outer Core**
  - Liquid layer
  - 2270 km thick
  - Convective flow of metallic iron within generates Earth's magnetic field

Earth's Layered Structure



8.4 Earth's Layered Structure

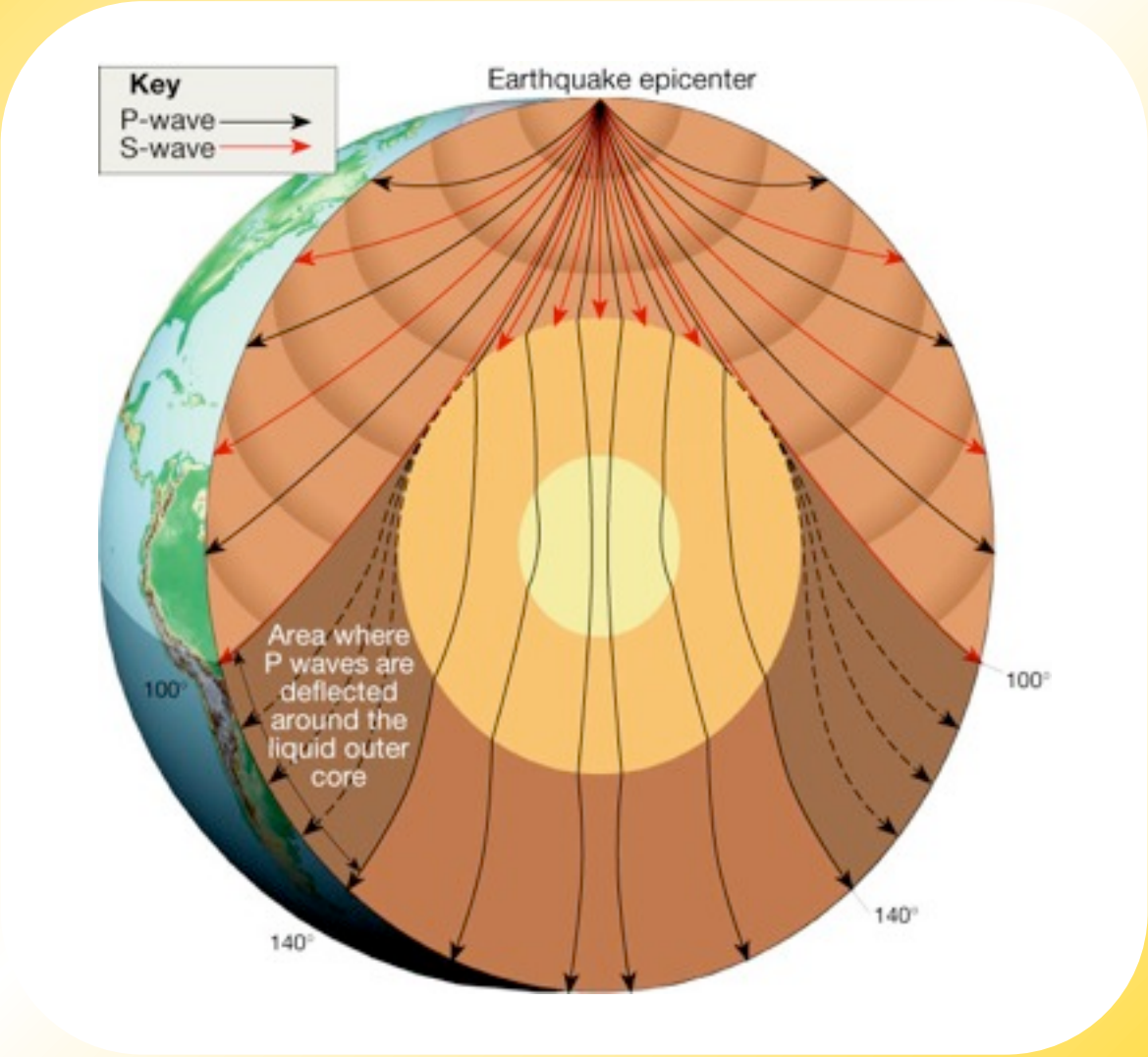
Discovering Earth's Layers

- **Moho**
  - Velocity of seismic waves increases abruptly below 50 km of depth
  - Separates crust from underlying mantle
- Shadow Zone
  - Absence of P waves from about 105 degrees to 140 degrees around the globe from an earthquake
  - Can be explained if Earth contains a core composed of materials unlike the overlying mantle

The Moho is ____.

1. **the boundary between the outer and inner core**
2. **boundary between the crust and the mantle**
3. **the material of which the mantle is composed**
4. **an area of the mantle that will not transmit seismic waves**

Earth's Interior Showing P and S Wave Paths



8.4 Earth's Layered Structure

Discovering Earth's Composition

- Crust
  - Early seismic data and drilling technology indicate that the continental crust is mostly made of lighter, granitic rocks.
- Mantle
  - Composition is more speculative.
  - Some of the lava that reaches Earth's surface comes from asthenosphere within.

8.4 Earth's Layered Structure

Discovering Earth's Composition

- Core
  - Earth's core is thought to be mainly dense iron and nickel, similar to metallic meteorites. The surrounding mantle is believed to be composed of rocks similar to stony meteorites.